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ORIGINAL ARTICLE



Helical water wires

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ABSTRACT

A helitetrahedral model has been proposed to help explain reports of low-frequency oscillations in pure water following electromagnetic excitation at the hydronium ion cyclotron resonance frequency. The Lorentz force and the intrinsic structure constrain the motion of the H_3O^+ ion so that it enjoys a unique form of proton-hopping, one whose path is helical. This model may also explain the numerous previously observed cyclotron resonance (ICR) biological couplings for cations other than hydronium by merely substituting hydrogen-bonded versions of these for hydronium in the tetrahedral structure. Thus the effectiveness of resonance stimulation in biological systems is explained in terms of the enhanced conductivity and reduced scattering associated with proton-hopping. It is further shown that the addition of charge-balancing hydroxyl ions act to enable oscillatory electric dipole moments that propagate along the helical axis, giving rise to weak power ($\approx$ femtoWatts) radiation patterns. It is conceivable that the radiation associated with this process may play a role in the interactions at the interface between water and living matter.

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Introduction

To help explain a number of reports (Bogatina and Sheykina, 2014; D'Emilia et al., 2015, 2016; Fesenko and Gluvstein, 1995) indicating weak electromagnetic responses in pure water, it was proposed (Liboff et al., 2017) that following hydronium cyclotron resonance (ICR) application, water exhibits a helical component in its structure, mainly as a result of the proton-hopping properties of the hydronium ion. In the following, we expand on this concept. By arbitrarily incorporating the hydroxyl ion strategically inside the helical structure, one also finds a mechanism by which low-frequency electromagnetic waves can be generated. In addition, we propose a new solution to the long-lasting problem of explaining weak-field ion resonance observations. The basis for the proposed water structure comprises tetrahedral substructures, which, when added together, make up long helitetrahedral chains, in the form of Boerdijk–Coxeter helices (Liboff et al., 2017; Sadoc and Rivier, 1999). Each of the putative regular tetrahedra consisting of three water molecules and one hydronium ion at its four vertices corresponds to a restructuring of the basic Eigen ion (Eigen and deMaeyer, 1958). The effects in question (Bogatina and Sheykina, 2014; D'Emilia et al., 2015, 2016;

Fesenko and Gluvstein, 1995) have been observed solely in pure water where the equal concentrations of H_3O^+ and OH^- ions ($\text{pH} \approx 7$) apparently serve to maximize ICR coupling, which in turn appears to be required to form the tetrahedral water structure.

In the following, we add the hydroxyl anion to this picture, merely situating it at the center of each tetrahedron (Figure 1). This provides charge balance, particularly necessary in view of the need for equal concentrations of both ionic types. Equally important, it suggests a novel explanation for the aforementioned observations of oscillatory effects in water (D'Emilia et al., 2015; Fesenko and Gluvstein, 1995).

The helical water wire

Ordinarily Lorentz forces on moving charged particles directed perpendicular to the magnetic field do not result in helical motion unless an electric field is also present. However, in the present case the tetrahelix serves to constrain the positive charge to a helical path (Figure 2).

Because of the intrinsic structural parameters of the tetrahelix, particularly the repetitive positioning of H_2O molecules, we note that the motion we have ascribed to H_3O^+ ions is equivalent to moving its attached proton instead of the complete hydronium

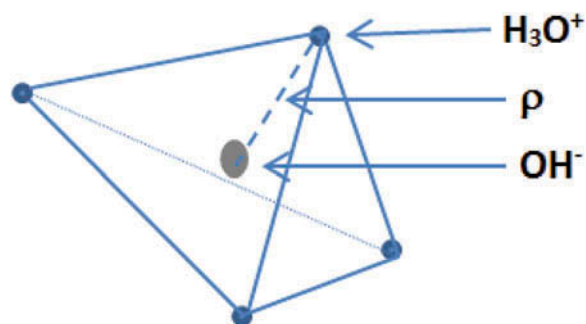


Figure 1. Proposed regular tetrahedral structure corresponding to $3\text{H}_2\text{O}\cdot\text{H}_3\text{O}^+\cdot\text{OH}^-$. The negatively charged hydroxyl ion sits at the center, separated from the positively charged hydronium ion by the tetrahedral circumradius ρ (dashed line), forming an electric dipole moment p with fixed magnitude ep . Water molecules occupy the three remaining vertices.

ion, thereby leaving behind a water molecule. We generalize this concept, suggesting that the progressive motion of a hydronium ion along the length of the tetrahelix in a properly oriented magnetic field is equivalent to the progressive motion of a single proton along the same path. This is shown in Figure 3, where, for simplicity's sake, the underlying helical shape is instead pictured as straightened out. This type of motion stemming from $\text{H}_3\text{O}^+/\text{H}^+$ proton transport is very similar to Grotthaus proton-hopping (Agmon, 1995), the clear distinction in this case being that the usual description of proton-hopping is not constrained by any specific structure, but is dependent merely on the availability of nearby water molecules. In any event, the net effect on water resulting from the application of an ICR combined magnetic field tuned to the hydronium ion is to create conducting pathways that are equivalent to helical water wires.

ICR proton-hopping for other cations

Despite numerous observations over the past 30 years (Fitzsimmons et al., 1995; Foletti et al., 2013; Gaetani et al., 2009; Galland and Pazur, 2005; Jenrow et al., 1995; Liboff, 2006; Lisi et al., 2008; Lovely et al., 1993; Novikov and Fesenko, 2001; Rozek et al., 1987; Smith et al., 1987; Thomas et al., 1986; Zhadin et al., 1998,

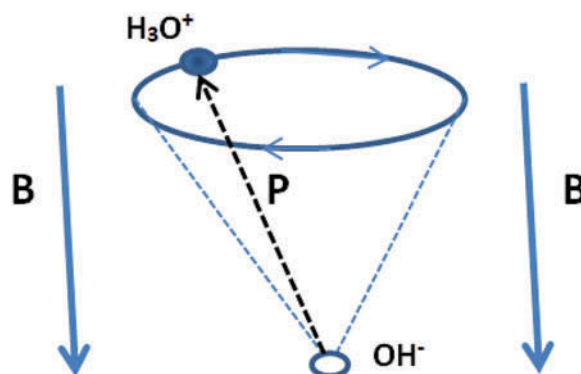


Figure 3. When a magnetic field B is lined up with the tetrahedral axis the dipole moment p moves in two ways, linearly along the axis and, as shown in this drawing, circularly around the axis. This motion occurs because the positive ion is constrained to the overall helitetrahedral structure. In this sketch the displacement of the OH^- ion is exaggerated: it is expected that the cation, anion and dipole are essentially coplanar.

1999) that appear fully consistent with predictions based on the ICR hypothesis (Liboff, 1985) there remains a long-standing difficulty (Adair, 1991; Halle, 1988) in finding a reasonable molecular explanation for low-frequency resonances in living tissues with large scattering rates such as found in liquids. Simply put, at extremely low frequencies, particles in resonance are unable to complete even one rotational cycle before being scattered away by thermal interactions. Prior to the discovery (D'Emilia et al., 2015) that weak-field ICR stimulation also occurs for hydronium ions in water, experimental observations were limited to biologically related ions such as Ca^{2+} , Mg^{2+} , K^+ , glu^+ , ... The proposed helitetrahedral model suggests a new approach to this question, one where proton-hopping also occurs for cations other than H_3O^+ . This requires a transitory state during which short-time hydrogen bonding occurs for the cation, allowing it to participate in the proton transfer. In effect, this equivalence can be pictured by merely substituting the appropriately stimulated cation for the hydronium ion in Figure 3.

The tetrahedral electric dipole moment

The pair of polar molecules H_3O^+ and OH^- included as part of the proposed tetrahedron pictured in Figure 1

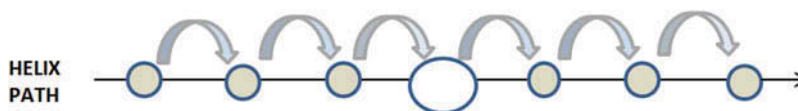


Figure 2. Proton-hopping. Portion of helical path stretched out into a line showing successive water molecules with H_3O^+ in the middle. Arrows represent all proton transfers from one molecule to the next beginning when H_3O^+ is on the far left and ending when H_3O^+ is on the far right.

constitutes an electric dipole moment with fixed magnitude $p_0 = ep$, where e is the electronic charge, 1.60×10^{-19} Coulombs. The separation ρ between positive and negative ions is the same as the circumradius of the tetrahedron, whose value is readily shown to depend solely on the tetrahedral edge length a , such that $\rho = (a/4)\sqrt{6}$ (Liboff et al., 2017). If we estimate the edge length of the basic tetrahedron to be 0.3 nm, the magnitude of this dipole moment is 2.9×10^{-29} Coulomb-meters. Because of the greater polar separation, this is rather large, almost five times the internal electric dipole moment of the water molecule, 6.2×10^{-30} C-m.

When the static magnetic field is oriented as shown in Figure 3, the dipole moves as a unit along the helix. Overall the motion of the dipole can be described as occurring simultaneously in two ways: first, as a linear displacement along the axis of the helix, and second, as a precessional motion around the axis. Note that the magnitude p_0 of the electric dipole is maintained as the positive charge follows the helical path. This occurs because the OH^- ion, serving as the center of rotation for the pair, sits at the force-free center (Mckinley and Schmidt, 1982) within each tetrahedron, enabling it to move freely from one tetrahedron to the next, thereby allowing Coulomb attraction to couple it to the negative ion as it executes its helical path. The net effect is that the magnitude of this dipole is maintained as it proceeds along the tetrahelix, the positively charged hydronium ion moving helically and the negative charge linearly. This only applies when the applied field B is directed along the tetrahelix axis; only for this orientation is the motion of the negative ion along the helical axis unaffected by the Lorentz force.

Electromagnetic emission

Because the rotating electric dipole in Figure 4 is time-varying, it will give rise to electromagnetic radiation. This emission can be evaluated. The rotating dipole is simulated mathematically by simultaneously superposing two perpendicular oscillating dipoles. If these two oscillating components are directed along the x - and y -axes, then the total dipole moment vector p will be given as

$$p = p_0 (i \cos \omega t + j \sin \omega t) \quad (1)$$

where ω is restricted to the cyclotron resonance frequency and i and j are the respective unit x and y vectors. By incorporating the electric and magnetic fields associated with p , one can derive S , the average

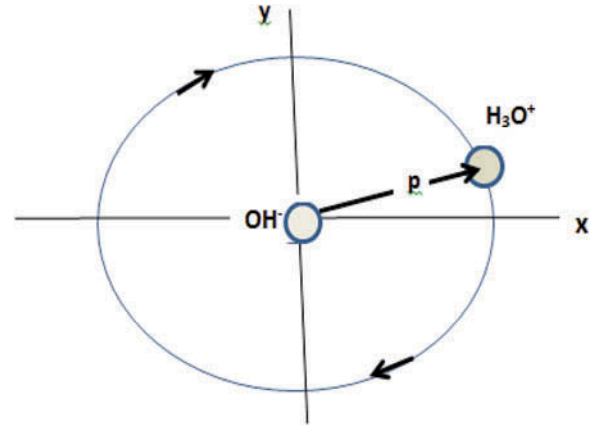


Figure 4. The helical motion of the electric dipole can be broken into two components: one directed along the z -axis, into the page, and the other, as shown here, as a rotation in the xy plane.

energy radiated per second (Griffiths, 2007). Expressed in terms of SI units, the expression for S is

$$S = \frac{\mu_0}{2} \left(\frac{p_0 \omega^2}{4\pi r} \right)^2 (1 + \cos^2 \theta) \quad (2)$$

where μ_0 is the permeability of free space, equal to $4\pi \times 10^{-7}$ Tm/A, p_0 has already been estimated at 2.9×10^{-29} Cm and θ is the angle made by r , the radius vector away from the z -axis. We can calculate the value of $S_0 = \frac{\mu_0}{2} \left(\frac{p_0 \omega^2}{4\pi r} \right)^2$ by making two arbitrary assumptions, for r and for ω . If we let $r = 1 \times 10^{-9}$ m and set the ICR frequency at $f = 50$ Hz, such that $\omega = 100\pi/\text{sec}$, then S_0 equals $2\pi \times 10^{-7} \times (2.3 \times 10^{-16})^2 = 4.8 \times 10^{-38}$ Watts. This number, expanded to reflect the molar quantities (≈ 18 g) of water, becomes 3×10^{-14} W. The latter part of Equation (1), $(1 + \cos^2 \theta)$, determines how this weak power is distributed spatially, with the maximum signal occurring when θ is either 0° or 180° , that is, when the radius vector is directed in either direction along the helical axis. When r points perpendicular to this axis, such that $\theta = 90^\circ$, the signal is minimized to half of what it is when maximized. That is, $S = 2S_0$ for $\theta = 0$ or $\pi/2$ and $S = S_0$ for $\theta = \pi/2$.

We note that this emission only occurs as long as the H_3O^+ resonance stimulation is applied, seemingly at odds with the observations (D'Emilia et al., 2015; Fesenko and Gluvstein, 1995) that electromagnetic oscillations occurred subsequent to the removal of the resonance stimulation.

Discussion

There presently is great interest in the physical properties of water, in large measure due to two independent research areas, one derived from the theoretical prediction of

coherent domains (Del Giudice et al., 2002) and the other reflecting the experimental observations of exclusion zones (EZ) (Pollack, 2013). The present work appears not to involve either coherent domains or EZ water. To the best of our knowledge, there have not been any previous suggestions that water may form helical structures, with the sole possible relevance limited to a report (Bai et al., 2006) involving ice constrained in carbon nanotubes at high pressures. On the other hand, a number of reports (Sheperd et al., 2005; Shimkevich and Shimkevich, 2011) have shown that helicity is increased for biological substances, particularly proteins, immersed in water.

We have shown that the tetrahedral water structure lends itself to ion resonance coupling, specifically for the hydronium ion, but probably also for cations in general. When ICR was first hypothesized by Liboff (1985) as an explanation for Blackman's discovery (1985) of a nonlinear response in chick brain to low-frequency magnetic fields, he also advanced a tentative model, arguing that the helical hydrophilic structures within membrane-bound ion channels might be the cause of this response. However, it was difficult to overcome some intrinsic problems, including the disparity in predicted and observed transit times associated with ion channel transport. The helicity modeled in the present work is in strong contrast with that found in ion channels. Not only is the proton transport time along the tetrahelix now a function of the ICR frequency but questions related to scattering are less important because of the increased conductivity due to proton-hopping. Because of the direct way in which the helitetrahedral water model explains the remarkable effects of ICR stimulation on water structure, we have concluded that this model may also provide an explanation for weak-field ICR coupling of other cations to biological systems.

This argument is strengthened when considering that the experimental requirement on pure water necessary to observe these effects, $18.2 \text{ M}\Omega\text{-cm}$ (D'Emilia et al., 2015, 2016), implies that equal concentrations of H_3O^+ and OH^- ions are required. Since the cationic ICR effects in question have been found not in pure water but in biological systems, we suggest that these effects may have less to do with purity *per se*, but more to do with pH. That is, the effects occur equally well in pure water or in biological matter since both exhibit a pH of about 7. This conclusion also implies that all the effects linked to ICR exposure in biological systems must ultimately involve the properties of water.

Introducing the hydroxyl ion as a component of the basic tetrahedron provides a rationale for an electric dipole moment of constant magnitude that moves along the helix while oscillating at 90° to the helical axis, thereby acting to radiate power. This is consistent

with recent, unexplained observations of electromagnetic emissions from pure water (D'Emilia et al., 2015; Fesenko and Gluvstein, 1995; Liboff et al., 2017), but inconsistent with some of these reports claiming that these emissions persisted for periods as long as 1 h after the stimulating ion resonance signal was removed. One possible answer to this inconsistency might be to suggest that the proposed water chains can terminate on interfacial surfaces, which would allow a certain degree of charge storage, resulting in an electric polarization that dissipates over time due to damped oscillations in the water wires.

The fact that water underlies the biological effects due to ICR stimulation coupled to the altered structure following this stimulation, as well as the subsequent weak electromagnetic emission, begs the question about possible biological significance. We think it is more than likely that the consequences of this proposed helitetrahedral water structure and its associated radiation are realized at the water-biological interface. It is interesting in this regard to ask whether such tetrahedral water chains might be spatially oriented relative to biological surfaces. We therefore speculate that these chains probably are oriented at 90° to biological surfaces to maximize whatever effects that might follow electric polarization at these surfaces, including, for example, the helical water chain possibly serving as a shuttle to improve the delivery of charge to the biological entity.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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